The Role of Sleep and Dreams in Memory

Madeleine Brodbeck

Dave Brodbeck

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Abstract

There are two types of dreams that are experienced during sleep. One type occurs during SWS and is characterized to have more episodic information. The other occurs during REM. After periods of sleep rich in SWS, episodic memory is better recalled. After periods of sleep rich in REM, procedural memory and emotional information is better recalled. There are various proposed mechanisms as to why memory may be consolidated during sleep or dreaming. There also various theories surrounding the origin of dream content. The importance of the hippocampus and the amygdala are key in both of these explanations. The fact that emotional information is better recalled during REM (when other episodic information is not) could be linked to research to do with memory and the effects of cortisol. Research in this field is still limited by current technology and the potential simplifications of sleep and dream stages.

Memory and sleep are two areas that have been extensively researched in psychology. However, it is only recently that the two schools have merged and worked together in order to study the relationship between sleep, dreams, and memory. There is a lot of evidence now that tells us that memory consolidation does occur while we are sleeping (Paller & Voss, 2004). The mechanisms for how sleep or dream states consolidate memory are still debated. This uncertainty possibly arises due to some issues with how this research is conducted and the limits of our technology and understanding of the brain. Some aspects of the research that are well researched are the different stages of sleep, their types of dreams, and the types of memory consolidated during these stages.

There are four stages of sleep, three in non-random eye movement (NREM) and random eye movement on its own (REM) (Hobson, Pace-Schott & Stickgold, 2000; Nielson & Stenstrom, 2005; Paller & Voss, 2004; Payne & Nadel, 2004; Stickgold, Hobson, Fosse & Fosse, 2001). The third stage of NREM is also known as slow wave sleep (SWS). NREM sleep comes before REM, the specific order being stage one, two, three, and finally REM. There are two types of dreams that a person has while they are sleeping. One type occurs during rapid eye movement (REM) sleep, while the other occurs in stage 3 non-rapid eye movement (NREM) sleep, or slow wave sleep (SWS) (Hobson *et al.*, 2000; Payne & Nadel, 2004). SWS dreams occur in early sleep, and these are characterized as being much more realistic than REM dreams. NREM or SWS dreams often have information relating to recent events or in other words, contain episodic content. REM dreams, on the other hand occur later in sleep. REM dreams contain bizarre situations and events occurring in

dreams are usually disjointed. REM dreams are also reported as being more emotional than NREM dreams. There is still some disagreement that these two types of dreams are not distinctive from each other, and that REM and NREM dreams generally consist of the same types of characteristics during sleep (Hobson, et al. 2000).

One of the more recent findings of this research is that different types of memory are consolidated during different stages of sleep. It seems that emotional memories are better consolidated during REM compared to SWS, or no sleep. Wagner, Gais and Born (2001) had participants read either an emotional text or a neutral one and had them sleep with monitors to record their sleep states. There was also a group of participants who did not sleep between learning and recall of the task. In general, those participants who slept did better on the task. In general, the emotional text was also better remembered the neutral text. Relating to specific stages of sleep, Wagner *et al*. (2001) found that participants who had REM rich sleep recalled the emotional text better than those participants who had slow wave rich sleep. Nishida, Pearsall, Buckner & Walker (2008) had participants study different emotional and non-emotional pictures before and after a nap for 90 minutes. There was also a second group of participants who stayed awake for the 90 minutes between the two study phases. Participants who napped had better recall for emotional pictures, but not neutral ones. In the napping group, the amount of REM the participants had positively correlated with better recall for the emotional words. This implies that the longer the participants were in a REM phase, the better they

recalled emotional information. The no nap group had poorer recall for neutral or emotional pictures compared to the nap group.

In order to understand why emotional information is better recalled after REM, the first course of action would be to look at the brain while people are sleeping. In general, it is known that the amygdala is less active during wakefulness than during REM (Nielson & Stenstrom, 2005). Maquet et al. (1997) used a PET on participants (n=7) while they were sleeping (who also remembered their dreams). Maquet *et al*. (1996) investigated blood flow to areas in the brain during REM sleep. These included areas with less blood flow and more blood flow during REM sleep. There was increased flow of blood to both amygdaloid complexes, which could explain why emotional memories are better remembered after REM sleep. It also gives an explanation as to why REM dreams are so emotional. Areas with less blood flow had no efferent connections to the amygdala. Amygdaloid complexes are implicated in the formation and consolidation of memories paired with emotional stimuli. The authors suggest that the activation of these areas suggest that REM does indeed contribute to memory processing. The authors also suggest that these interactions may lead to the reactivation of components of memories, consolidating their traces.

Just like emotional memory is better consolidated during REM, there is a distinction of consolidation in different sleeping stages between episodic and procedural memory. During SWS episodic memories are better consolidated compared to other stages of sleep or no sleep, but during REM sleep procedural memories are better consolidated compared to other stages of sleep or no sleep.

Plihal and Born (1997) had participants perform both a word list and mirror-tracing task. The word list was used to measure episodic memory, and the mirror tracing used to measure procedural memory. Each participant slept and had sleep measured with a polysomnogram. Participants who had sleep periods rich in SWS were better able to remember the wordlist than those with sleep periods rich in REM or no sleep. Participants who had sleep periods rich in REM were able to perform on the mirror tracing better than those with sleep periods rich in SWS or no sleep. Firstly, this implies that sleep in general is good for memory consolidation. This also implies that memory consolidation was better for episodic information after SWS, and that memory consolidation was better for procedural information after REM sleep. Tucker *et al.* (2006) investigated a similar topic, but focused on a nap during the day time (in the afternoon, at 1:00 pm). Tucker had participants in two groups, one group had naps that consisted solely of REM, and the other group stayed awake. The participants in the sleep group had an hour to fall asleep, and would be awoken when the EEG showed SWS was coming to an end, in order to stop the onset of a REM phase. Participants in both groups performed a paired-associate word list task (episodic memory) and a mirror-tracing task (procedural memory). Similarly to Philal and Born (1997), Tucker et al found that participants who partook in a late afternoon nap did significantly better on the paired work list task than participants who had no sleep. Tucker *et al.* also found that there was no difference between the sleep and no sleep group for procedural memory.

Payne and Nadel (2004) theorize that the recall of episodic memory in SWS and procedural memory during REM has something to do with levels of cortisol

(commonly known as the stress hormone) while sleep occurs. Throughout the night, cortisol levels gradually raise as one sleeps. The hippocampus is known to be influenced by cortisol, as high levels of stress can impede its functioning. The hippocampus is therefore able to function in early sleep due to these lower levels of cortisol, implying that during SWS the hippocampus functions better than during REM. The hippocampus is known for being important for episodic memory. During SWS, due to lower cortisol levels, better episodic memory consolidation can occur. The hippocampus is less important in regards to procedural memory. The phenomenon that procedural memories are better recalled after REM could be because they can be consolidated throughout the night without disruption from cortisol.

It is likely that these processes are more complicated than simply the raising or lowering of cortisol; there could be other factors in play for the consolidation of memories (Payne & Nadel, 2004). This information does beg the question: is it something about the process of dreaming, which allows for this type of memory consolidation, or is there something else happening in parallel (like fluctuations in cortisol)? There are many theorists who believe that dreaming has a direct role in the consolidation of memories (Nielson & Stenstrom, 2005). There are various hypotheses as to how sleep or dreams consolidate memories. Some hypothesize that the appearance of memory elements helps consolidate these memories by reactivating memories in the brain, or perhaps aid in the recall of that information. In fact, during REM the firing of certain hippocampal neurons mimic what is found during a learning phase, which could imply that these associations would be

strengthened by long term potentiation (Paller & Voss, 2004). Paller and Voss (2004) theorize that memories are modified while we sleep. They also outline the usefulness of processing memories while dreaming. Paller and Voss (2004) believe that dreaming aids in coping strategies or behavioural changes. They theorize that sleep almost serves a therapeutic function when it comes to our memories, and strengthens connections in the neo-cortex to the hippocampus.

Of the different theories of the role of memory in dreams, all seem to attribute change in dream content to changes in the hippocampus (Nielson & Stenstrom, 2005). Increasing levels of cortisol during the night can be directly related to dream content (Payne & Nadel, 2004). During SWS there are lower concentrations of cortisol, and so the episodic content is intact and can play itself out in dreams. During REM there are higher concentrations of cortisol, which disrupts hippocampal neocortical connections. This leads to episodic content becoming disrupted and creating bizarre and disjointed events during REM sleep. During REM it has also been demonstrated that the dorsolateral prefrontal cortex (DLPFC), a functional area that deals with higher cognition, is deactivated (Stickgold *et al*., 2001). Its deactivation makes sense for the bizarreness, and lack of awareness during dreams. Stickgold *et al.* (2001) mentions that during REM there is an inhibition of hippocampal outflow. They theorize then, that the recollection of any episodic content during REM would have to be from weak neo-cortical associations. How REM uses these association is not known, but Stickgold *et al.* (2001) theorizes that it has something to do with associated emotions from the amygdala and medial orbitofrontal cortex (higher area for emotion), which are both very active during

REM. They theorize that is why REM dreams are so bizarre and emotional at the same time.

There is a final problem that should be addressed. REM shows a relationship with the consolidation of emotional information, but not general episodic information. Why is it that emotional episodic information is only consolidated during REM, but other episodic information is not? The amygdala is indeed more functional during the REM phase, which could imply better emotional consolidation. Looking at research by Payne *et. al*. (2006), some interesting conclusions could be drawn. Experimental participants were exposed to a test that induced stress and then showed a slideshow with both neutral and emotional episodic information. Payne *et al.* (2006) found that the recall of the emotional information was enhanced in the group of participants who had stress induced. They also found that the recall of the neutral information was worsened in the group of participants who had stress induced. If we think back to Payne and Nadel's (2004) research on cortisol, a hormone that is released during stress, this information seems to fit perfectly. As cortisol increases during the night while sleeping, it also aids in the consolidation of emotional information, as this research implies that stress increases the recall of emotional memories. The research by Payne *et al*. (2006) does not apply this information to dreaming or sleep, but it is not an unrealistic leap.

All this information gives quite a few implications into our cognition; unfortunately, there are some issues with studying dreams and memory. Dream stages are complex and function depending on how previous sleep states function as well (Paller & Voss, 2004). There could very well be different steps in different

stages of sleep, which lead to the consolidation of memories. We also do not yet have technology that can outwardly test the type of dream content in SWS and REM dreams: are they truly that distinct? Despite this, the research shows that during these certain stages there are different types of memory consolidation. During REM dreams, there is an enhanced recall for emotional information and for procedural knowledge. During SWS dreams, there is an enhanced recall for episodic information. There is also an interesting effect of cortisol on the hippocampus, which relates both to memory consolidation in different stages, as well as to dream content. It may seem odd as to how emotional episodic information is consolidated during REM, but it seems to have to do with the high activation of the amygdala during sleep. This emotional information consolidation could also have something to do with cortisol. A general hypothesis for memory consolidation during dreams is that dreaming about the content strengthens the connections for that memory. With more research and a furthering of technology in this area, more specific pathways can be studied to completely understand the relationship between dreams, memory and sleep.

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